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Integrated Effects of Wheat Residue and Phosphorus Application on Rice Productivity and Soil Health under Salt Affected Soils

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Abstract. A field experiment was conducted to determine the effect of crop residue incorporation along with P application on rice production under salt affected soil having pH 8.57, ECe 5.65 (dS/m), SAR 17.38 (mmol/L)½ and available P (3.9 mg/kg). The study was carried out at MK Farm, Farooqabad, Sheikhupura, Pakistan during Kharif season in 2009. Treatments were arranged using randomised complete block design (RCBD) with three replications. The treatments were control (T_1), straw incorporation @ 5 tonnes/ha (T_2), T_2+20 kg/ P_2O_5/ha (T_3), T_2+40 kg/P_2O_5/ha (T_4) and T_2+60 kg/P_2O_5/ha (T_5). The highest grain yield (4.407 t/ha) was recorded in treatment receiving 5 tonnes wheat straw along with 40 kg P_2O_5/ha which is 14.6% more than control and the lowest grain yield (3.847 t/ha) was recorded in control. Maximum P (0.37%) and K (0.13%) contents of grain were recorded where wheat straw was applied @ 5 t/ha along with 40 and 60 kg P_2O_5/ha whereby P content of control was (0.3%). The residual P was 5.7 mg/kg where wheat straw was applied @ 5 t/ha along with 40 and 60 kg P_2O_5/ha. The residual P in control was 4.3 mg/kg. It can be concluded that incorporation of residue enhanced the availability of P, K and Ca to plant roots. Under saline-sodic/sodic conditions, plant can better cope with salinity in the presence of calcium and K availability.

Keywords: wheat residue, rice productivity, salt affected soils

Introduction

Rice and wheat are the leading staple food crops of the people of southeast Asia. More than 90% of rice and 43% of wheat in the world is produced and consumed in Asia (Chauhan *et al*., 2012). The rice-wheat cropping system is highly nutrient exhaustive system hence causes a considerable depletion of soil nutrients (Zahir *et al*., 2011) therefore, consequently requires heavy use of fertilizers each year for the potential yields. Large responses of wheat and rice to fertilizers are well documented (Akhtar *et al*., 2009; Bakht *et al*., 2009; Shafi *et al*., 2007; Suman, 2004; Shah and Khan, 2003; Roder *et al*., 1998).

Soil C, N, burning of residue crop and replenishing soil fertility status has been studied by Khankhane *et al*. (2009), Byous *et al*. (2004), Gupta *et al*. (2003), Mishra *et al*. (2001), Sarma *et al*. (2000), Rasmussen and Parton (1994) and Raison *et al*. (1979). Burning of rice straw prior to sowing of wheat is still a common practice in central and northern parts of India.

About 50% of wheat crop is being harvested with combined harvester. The combined harvester leaves behind a large amount of loose straw in the field whose disposal or utilization in the short time is difficult and compelling farmers to burn the residue to get rid of it (Gupta *et al*., 2003). Since plant nutrients remain in the straw (approximately 35% N, 30% P and 85% K and 40-50% S) much of this can be recycled for subsequent crop growth after its decomposition (Byous *et al*., 2004).

In many studies, recycling of crop residues is reported to increase the organic carbon and nutrient contents; decreased soil bulk density and increased crop yields (Mehdi *et al*., 2011; Eagle *et al*., 2000; Misra *et al*., 1996). Thus, it is high time to explore how this precious resource can be utilized and managed from improving soil physicochemical characteristics and amelioration of salt affected lands for enhancing and sustaining productivity. A field experiment on salt-affected soil of Sheikhupura district is being conducted to determine the effect of crop residue incorporation with P on subsequent crop yield grown under variable soil salinity/sodicity.

Materials and Methods

A field experiment was conducted to determine the effect of crop residue incorporation along with P application on rice production at MK Farm, Farooqabad,

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Sheikhupura, Pakistan starting from summer 2008 and during Kharif (summer) season, 2009. Treatments were arranged using randomised complete block design (RCBD) with three replications. The treatments were Control (T_1), straw incorporation @ 5 tonnes/ha (T_2), T_2+20 kg P_2O_5/ha (T_3), T_2+40 kg P_2O_5/ha (T_4) and T_2 +60 kg P_2O_5/ha (T_5) as (DAP-Di ammonium phosphate). The wheat straw was incorporated in all the treatments except control plots (4×15 m each). The soil was prepared by puddling and a recommended dose of N and K_2O @ 100 and 50 kg/ha, respectively was applied to all treatments. Half dose of N and full dose of K were applied at the time of rice transplantation. The remaining ½ N was applied at tillering stage. The crop was irrigated with tube-well water throughout the growth period. Necessary plant protection measures were taken whenever required. Data on tillers, plant height, panicle length, number of grain/panicle, 1000 grain weight and straw and grain yields were recorded at the time of crop harvest. Plant samples were oven dried at 60 °C to a constant weight and was dry matter yield recorded. Grain and straw samples were ground using Wiley mill. Ground plant samples were digested in perchloric nitric acid (2:1 1N) mixture (Rhoades, 1982) to estimate Na, K, Ca and Mg by atomic absorption spectroscopy. The data thus obtained were analysed using MSTATC and treatments were separated using LSD test. Tube-well water being applied contains soluble salts slightly above permissible limit of 1.5 dS/m (Table 1). However, residual sodium carbonate in tube-well water is high posing serious threat of sodicity. Soil textural class is loam having salinity and sodicity (Table 1).

Table 1. Physicochemical analysis of the soil and irrigation water at MK farm

Parameters	Value	
	Soil	Irrigation water
pH (1:1)	8.57	8.3
ECe (1:1) (dS/m)	5.65	1.6
SAR (m.mole/L)$^{1/2}$	17.38	__
RSC (meq/L)	__	14.7
HCO_3 (meq/L)	__	16.3
$CaCO_3$ (%)	7.00	__
OM (g/kg)	13.3	__
Available P (mg/kg)	3.9	__
Sand (%)	33	__
Silt (%)	42	__
Clay (%)	25	__
Texture class	Loam	

Results and Discussion

The data in Table 2 indicated that crop residue incorporation alone and with P incorporation to rice showed statistically significant effect on plant height, number of tillers, panicle length, number of grains/panicle, straw and grain yield. Maximum number of tillers (31) was recorded in treatments receiving residue incorporation along with 40 and 60 kg P_2O_5/ha as compared to control (20). Increase in number of tillers due to residue incorporation and phosphorus application above recommended dose showed that more phosphorus is needed against recommended dose. Moreover, phosphorus contribution coming from residue is beneficial. Maximum panicle length (30.66 cm) and grain per panicle (211) were attained as a result of wheat straw incorporation @ 5 tonnes/ha and 20 kg P_2O_5/ha. Maximum straw yield (24.11 t/ha) was attained @ 5 tonnes/ha along with 20 kg P_2O_5/ha. Grain yield (4.407 t/ha) was the highest in treatment receiving 5 tonnes wheat straw along with 40 kg N/ha (T_4) which is 14.6 % more than control treatment, and the lowest grain yield (3.85 t/ha) was

Table 2. Effect of wheat straw incorporation supplemented with P on growth, straw and grain yield of rice at MK Farm

Treatments	Plant height (cm)	No. of tillers	Panicle length (cm)	No. of grains/ panicle	1000 grain weight (g)	Straw yield (t/ha)	Grain yield (t/ha)
T_1	128.00 c	20.00 d	25.66 d	160.33 d	26.33 c	16.560 e	3.847 b
T_2	129.33 c	22.33 c	29.00 b	193.66 b	28.33 b	20.133 c	4.287 a
T_3	131.00 b	24.33 b	30.66 a	211.66 a	27.00 bc	24.107 a	4.327 a
T_4	139.66 a	31.00 a	27.33 c	184.33 c	30.00 a	18.480 d	4.407 a
T_5	139.00 a	31.00 a	27.33 c	194.33 b	27.00 bc	22.437 b	4.233 a
LSD	1.753	1.786	1.375	5.139	1.575	0.3622	0.1786

recorded in control. However, all of the treatments except control were statistically at par. Similar trends were observed in all parameters of earlier rice and wheat crops. The enhanced yield in treatments receiving residue incorporation showed significant improvement in soil fertility status and this will improve with the passage of time as compared to control treatment receiving chemical fertilizer at recommended rate (Larney and Angers, 2012). Microbial activity would have increased due to residue incorporation and P addition helping rapid decomposition. Residue incorporation is viable option to maintain soil fertility and soil health replacing/supplementing fertilisers.

Ionic concentration in straw and paddy was found to be statistically significant except Mg in grain. Sodium uptake was higher in rice grain in control and found lower in all the other treatments receiving wheat residue incorporation @ 5 t/ha (Fig. 1). This showed that crop residue incorporation reduced sodium uptake in rice straw and grains. Gaind and Nain (2011) reported that paddy straw improved soil quality. Ca and K uptake by grain and straw was the highest where, wheat straw was applied @ 5 t/ha Table 3.

It can be concluded that incorporation of residue enhanced the availability of K and Ca to plant roots. Under saline-sodic/sodic conditions, plant can better cope with salinity in the presence of calcium and K. The presence of calcium also enhances rehabilitation of sodic soils which is prevalent in soil at this location

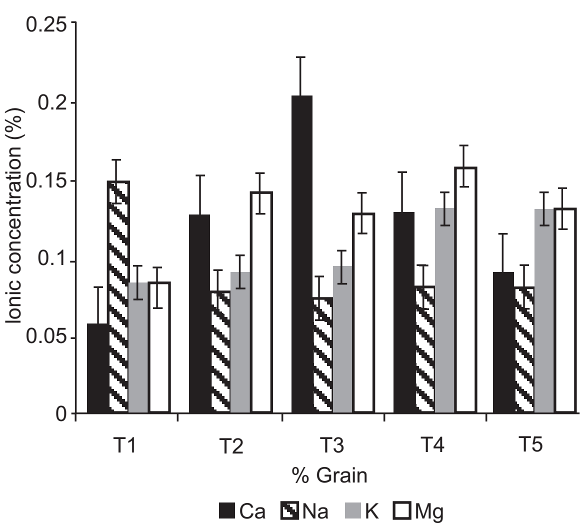

Fig. 1. Effect of wheat straw incorporation supplemented with P on Na, K, Ca and Mg uptake % by paddy grain.

Table 3. Effect of wheat straw incorporation supplemented with P on Na, K, Ca and Mg uptake % by paddy straw at MK Farm

Treatment	Straw (%)			
	Ca	Na	K	Mg
T_1	0.347 cd	0.213	2.283	0.900
T_2	0.290 d	0.143	2.353	1.270
T_3	0.377 bc	0.240	2.123	1.010
T_4	0.423 ab	0.183	1.963	0.910
T_5	0.443 a	0.190	2.133	0.873
LSD	0.05954	NS	NS	NS

in rice-wheat growing area. The residual available P was 4.3 to 5.7 mg/kg where wheat straw was applied @ 5 t/ha along with 40 and 60 kg P_2O_5/ha while, in control it was 4.3 mg/kg (Table 4). It can be concluded that incorporation of residue enhanced the availability of P, K and Ca to plant roots. As a result, rate of rehabilitation of sodic soil will improve significantly. These findings are in agreement with the results of Ahn *et al*. (2010) and Antil and Singh (2007).

All the agronomic practices and plant protection measures were same except crop residue incorporation alone and with P incorporation. The most economical treatment T_3 (5 tonnes wheat straw/ha and 20 kg P_2O_5/ha) gave 0.606 marginal rate of return followed by T_2 (5 tonnes wheat straw/ha) having 0.532 MRR. Secondly the net benefits in case of 5 tonnes wheat straw incorporation and 20 kg P_2O_5/ha were 12% higher than control treatment (Table 5). Treatments receiving 5 tonnes straw incorporation alone gave 5% higher net benefits than control treatment. Both the economic indicators (net benefits and marginal rate of return) exhibited that treatment receiving 5 tonnes wheat straw/ha and 20 kg P_2O_5/ha is viable option to enhance crop productivity and soil fertility.

Table 4. Soil available P content after rice harvest (the third crop)

Treatments	Residual P (mg/kg)
T_1	4.3
T_2	5.1
T_3	5.4
T_4	5.6
T_5	5.7

Table 5. Economic analysis, partial budget analysis and dominance analysis of crop residue management with P on rice production at MK farm

Treatments	Control	Straw incorporation	T2+20 kg P_2O_5/ha	T2+40 kg P_2O_5/ha	T2+60 kg P_2O_5/ha
Input cost	0	12,500	15,000	17,500	20,000
Total cost that vary	0	12,500	15,000	17,500	20,000
Yield grain kg/ha	3847	4287	4327	4407	4233
Yield adjusted (10% low)	3462	3858	3894	3966	3810
Output price Rs./Kg	24	24	24	24	24
Yield Straw kg/ha	16560	20133	24107	18480	22437
Yield adjusted (10% low)	14904	18119.7	21696.3	16632	20193.3
Output price Rs./kg	3	3	3	3	3
Gross field benefits	127807	146958	158552	145087	152013
Net benefits	127807	134458	143552	127587	132013

Dominance analysis

	TCV (total cost that vary)	NB	VCR
T_3	0	127807	
T_2	12,500	134458	11:1
T_3	15,000	143552	9:1
T_4	17,500	127587	7:1
T_5	20,000	132013	7:1

Marginal analysis

	TCV	MC	NB	MNB	MRR
T_1	0	0	127807		
T_2	12,500	12,500	134458	6651	0.532
T_3	15,000	15,000	143552	9094	0.606

MNB = marginal net benefit; MRR = marginal rate of return; MC = marginal cost; TCV = total cost that vary; VCR = value

Conclusion

The highest grain yield (4.407 t/ha) was recorded in treatment receiving 5 tonnes wheat straw along with 40 kg/P_2O_5/ha, which is 14.6 % more than control and the lowest grain yield (3.847 t/ha) was recorded in control. Maximum P (0.37%) and K (0.13%) contents of grain were recorded where wheat straw was applied @ 5 t/ha along with 40 and 60 kg P_2O_5 ha, whereby P content of control was (0.3%). The residual P was 5.7 mg/kg where wheat straw was applied @ 5 t/ha along with 40 and 60 kg/P_2O_5/ha. The residual P in control was 4.3 mg/kg. It can be concluded that incorporation of residue enhanced the availability of P marginally, K and Ca to plant roots under saline-sodic/sodic conditions. For sizeable increase in P residual availability P foliar application may be the better option under saline sodic soil Kaya *et al*. (2001).

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